The Landuse Changes in the Kansai Region Observed by LANDSAT Satellite

The Landuse Changes in the Kansai Region Observed by LANDSAT Satellite

Taiichi ITO

ランドサット衛星から見た関西地方の土地利用の変遷

伊藤太一

Abstract

14 years have passed since LANDSAT MSS data became available. However, in spite of considerable expectation, very few applications of the data can be found in Japan. In a large scale analysis, the 185 km by 185 km LANDSAT image has no substitute, but most of the application in Japan is concerned with rather small areas. Therefore the feasibility of using LANDSAT MSS data, and the problems in a regional-level landuse classification are discussed in this paper.

There are two main objectives in this study: first, to clarify the advantages and problems of LANDSAT image processing method in a regional scale and second, to analyze the changes of landuse over 13 years based on the two classified scenes of the same region.

In regard to the former objective, the first and constant problem was selecting suitable scenes. How to store the data in a usable format was another issue. There are a lot of papers on advanced application techniques, but no books or papers deal with such issues in detail.

Many residents in urban area in Japan feel that our open space has been rapidly declining and that preserving forested areas is an urgent issue. By comparing Fig. 8 and 9 it is obvious that urban landuse is spreading over surrounding areas as recognized by many people. However, detailed observation clarified that most of those recently urbanized lands were agricultural ones, and that forested areas declined very little in 13 years. In addition, as a result of reclamation, bare and urbanized areas along the Osaka Bay were created.

要旨

ランドサットのデータが供給され始めてから14年を経た。だが，日本においては当初の期待の大きさのわりには，その解析技術的な研究の数に比して，その応用例はあまり多くない。また，

185km四方が同時に1シーンのデータに収められているのが，ランドサットデータの特色であるにもかかわらず，それに相当するような範囲地域を扱った応用例を見出すことができない。そこで，農地とか林地とかの限定された地域ではない広域の土地利用を知るための手法としてランドサットデータの解析がどの程度有効であるかを見極めること，および，その問題点について明らかにするために本研究をまとめた。すなわち，本研究の目的は2つに大別される。ランドサットデータによる土地利用分類手法の有効性および問題点を明らかにすることと，分類された1972年と1985年の土地利用図から13年間の変遷の傾向を明らかにすることである。

第一のプロセスに関しては，最初ということもあり多くの試行錯誤を繰り返した。まず，問題となったのは適当なシーンの選択である。16—18日おきに同一地域のデータが得られるはずであるが，実際には雲で覆われていて使えないものが多かった。また，入手したデータをどうしたら利用できるように格納できるのかという初歩的な点について触れた文献が見当たらなかった。土地利用区分は画像処理専用システムを用いて行なったが，精密に分類する過程を数十回も繰り返す必要があった。

第二の土地利用分類の結果に関しては，地域ごとの特性を明らかにするために16ブロックに対象地域を区分した。予想されたように市街地は13年間に周辺部に拡大し，農地が住宅地化されたが，樹林地は大規模な造成地をのぞいて，ほとんど減少していない。また，海岸部においては埋め立てによる裸地および市街地の増加が顕著であった。

1. Introduction

14 years have passed since the first LANDSAT satellite was launched in 1972. During this period a lot of researches on remote sensing have been carried out. However, most of them deal mainly with the technical aspects of remote sensing. In comparison with the abundance of such technical research, the amount of applied use is not so great as expected. Furthermore, most of the application methods cannot be easily utilized by people with different image processing system.

The Data Processing Center of Kyoto University has a image processing system called PROSID. The author had an opportunity to use this system in order to process two sets of LANDSAT MSS data. This paper discusses not only the results but also the problems he experienced in the process. This is important because most of other papers explain the advantages and accomplishments, and omit their problems and failures, which is misleading.

In short, this paper discusses two issues: first, the problems and effectiveness of the techniques and systems of remote sensing, and second, the product, that is the landuse change itself. The second issue is often discussed in various fields as deterioration of living environment. Almost everybody believes that open space in our cities and the surrounding areas is rapidly decreasing, but the author was not sure if it is true regarding a region surrounded by mountains. Therefore, he tried to find any trends in the landuse change.

2. On Landsat MSS Data

LANDSAT TM (Thematic Mapper) data has been available since 1984. This TM data has more detailed information on the land surface than the MSS (Multispectral Scanner) data. However, following landuse changes in 13 years is the main purpose of this study, therefore MSS data of 1972 and 1985 were chosen to make comparisons. One image of MSS data covers an area of 185 km by 185 km, and consists of 4 bands, which cover the wave length of 0.5-0.6 μm, 0.6-0.7 μm, 0.7-0.8 μm, and 0.8-1.1 μm respectively. Each pixel covers an area of 79 m by 79m.

In this study, two scenes of the Kansai region (pass 110-row 36) were chosen (Fig. 1 and 2). The data of October 24, 1972 by LANDSAT 1, and of June 5, 1985 by LANDSAT 5 were selected after searching for suitable scenes. The former is one of the oldest LANDSAT data, since the satellite was launched on July 23, 1972.

Both scenes are recorded in magnetic tapes with BIL (Band Interleaved by Line) format. Selecting scenes from such different season for comparisons should have been avoided, however, it was impossible to find a clear scene taken in the same season. One LANDSAT satellite covers the same area every 16-18 days, but only one or two cloud-free scenes can be obtained every year due to the climate of central Japan. For this reason, there was no alternative to selecting these two scenes.

3. Preprocessing of the Data

The area chosen is about 126 km by 110km as shown on the map (Fig. 1) , which is an area consisting of 1524×1366 pixels. If 3 bands are used to classify the landuse, a storage space of 1524 × 1366 × 3×2 bytes is required in order to process 2 scenes. Processing such a large number of data not only requires a long computation time but also causes serious storage space problems. For this reason, in the preprocessing, the number of pixels was reduced to 771×683 by eliminating the odd numbers. Then the data was divided into four files because the maximum size of data displayed and manipulated on the CRT at one time is limited in 512×512 pixels.

The data of 1985 is said to have been corrected by NASDA (National Space Development Agency of Japan), but the correction is not very reliable. The data of 1972 recorded by NASA (National Aeronautics and Space Administration), is not corrected at all. For the purpose of making comparisons of these two scenes, data for both were corrected based on 1:200000 scale map by Geographical Survey Institute of Japan by selecting some ground control points. After geometric correction, normalization of data distribution and noise removal were done.

Each scene consists of following 4 files.

1) Lon. 134° 37'30" E. to 135° 20'00" E. (399 pixels)
   Lat. 34° 30'00" N. to 35° 10'00" N. (455 lines)

2) Lon. 134° 37'30" E. to 135° 20'00" E. (399 pixels)
   Lat. 34° 10'00" N. to 34° 30'00" N. (228 lines)
3) Lon. 135° 20'00" E. to 136° 00'00" E. (372 pixels)
   Lat. 34° 30'00" N. to 35° 10'00" N. (455 lines)
4) Lon. 134° 20'00" E. to 136° 00'00" E. (372 pixels)
   Lat. 34° 10'00" N. to 34° 30'00" N. (228 lines)

4. Analyzing Process

The maximum likelihood method is employed in the analysis. PROSID image processing system (Fig. 3) can classify an area of 512×512 pixels based on the data of training areas, which are determined on the display by drawing polygons with the attached cursor control ball. The usual process is the following:

4-1. Data Transportation

The original data stored in CCTs (Computer Compatible Tape), which were purchased from RESTEC (Remote Sensing Technology Center of Japan), were temporally stored in the mass storage system of the main system (FACOM M-382) for preprocessing and for selecting study areas. The original MSS data consisted of 4 bands with 3548 pixels and 2983 lines. This means that a storage space of as much as 42 mega-bytes is required to keep a set of original data, since each pixel consists of one byte (256 ranges).

Then the data was retransferred to CCTs again in a converted format acceptable for the PROSID image processing system. This data stored in the tape was loaded on the magnetic tape station at the image processing system (Fig. 4). Thus the data was transferred to a disk system, in which one scene is stored as 4 master image files corresponding to 4 bands of MSS data.

4-2. On-Screen Representation

Three of these master image files were transferred to the refresh memory of the image display for representation. At this stage, the processed image can be displayed on the CRT (Cathode Ray Tube) of PROSID. Usually a false color image is used for the preparation of analysis. The false color image consists of 3 band data; band 4, 5 and 7 are often chosen because band 6 and band 7 have similar values. Then blue, green and red are allocated to these 3 bands.

4-3. Selecting Training Areas

By observing and operating this false color image in addition to other sources of landuse information like topographical maps, aerial photographs and the result of field survey, training areas were selected. 1:25000 scale landuse maps from the Geographical Institute of Japan were often used to identify certain landuses with the help of the zooming function of PROSID. In regard to the landuse of 1972, the experiences and memories of two land planning consultants were very helpful.

In the early stages of this analysis, more than 10 categories of the landuse were chosen, but finally they were merged into 6 categories: water surface, woodland, urbanized area, agricultural field, bare land, and cloud and the shade.

4-4. Classification and the Output

After setting all the training areas, the scene on the CRT was classified into above mentioned 6 categories. The results of the maximum likelihood method analysis is not only shown on the display but can also be stored on a disk. This classified data once stored, was transferred back to a CCT at the magnetic tape station for further operation in the main computer system.

In order to obtain hard copies of classified data, in addition to Polaroid photographs, an ink-jet color plotter named APPLICON installed at the main system was used. This color plotter (Fig. 5) can address a 0.2032 mm pixel. By gathering 4×4 pixels, 16 tones for each color can be logically selected. In this case, a maximum of 1050×688 pixels can be represented on one map. In other words, the four separated files can be shown in a composite map since the total pixel number of the area is 771×685. This merged classified data is shown in Figure 8 and 9. Two programs for this process were written. First one merges four data sets into one, then the second reads the data and allocates a color to each pixel to generate a color hard copy.

Another program for drawing a changed-landuse map was also written. This program designates colors to certain landuse changes then produces a color hard copy as shown on Fig. 10.

As mentioned in chapter 4-4, the color plotter outputs are based on four separately classified subscenes. Therefore there are some inconsistencies at the seams of each subscene.

5. Results of Classificaton

Strictly speaking, we classify each pixel of the LANDSAT data according to the values of each band, which reflects the ground-surface conditions. Accordingly, the results are not truly landuses but are rather surface conditions. We recognize various landuses not only by the color of objects but by their forms, our experiences and knowledge. Therefore, what we recognize as rice paddies can be classified as either bare land or water surface in the same scene, depending on the stages of the season. For this reason a lot of discussion was focused on this issue.

5-1. Issues Raised

Most of the applications of LANDSAT data, that have appeared in academic papers are limited to certain landuses or features like agricultural lands or forests. In their cases, it is easy to make a detailed classification since the image of the most suitable season can be identified and then the operation can be focused upon detailed differences of the landuses.

As explained in chapter 2, selecting a suitable scene requires tough decisions. The selected data must satisfy two crucial conditions; first, the area should not be covered with clouds, and second, the season should be suitable enough to distinguish the proposed landuses. The seasonal factor is very critical when plants become an object of classification. Their changes are not uniform; each species has its own growth patterns. For instance, spring and autumn scenes are said to be suitable to distinguish tree species because the deciduous trees have distinctive colors. However, these seasons are not suitable for classifying agricultural lands since some of them will be regarded as bare lands after harvest while others, like rice fields, may be mistaken for ponds because their rice is young and the fields are newly irrigated.

Clouds are almost always a source of trouble. The data of 1985 (Fig. 2) shows a rare scene because only a few of 10,583,684 pixels are clouds and their shadows. In the scene of 1972 (Fig. 1), there are some cloud-covered areas. Those areas are the Kameoka Basins, Izumi Mountain Ranges, Awaji Island and the surrounding Seto Inland Sea. Usually clouds are easily distinguished for their extremely high values, but the clouds over the Seto Inland Sea are transparent. Such transparent clouds change the values of land surface, and make a correct classification of the covered areas difficult.

5-2. Outputs

The six classes of the landuse were determined after various trials. If the classification had been aimed at some specific categories, it would have been possible to make a detailed distinction. However, this study was aimed at grasping at a general trend on a regional level. It is obvious that six categories are not enough to express the landuse of the Kansai region. Therefore, several landuses are included in one category, and the distinction between the classes is not always clear. Since the size of an original pixel is about 80m × 80m, the value of one pixel may reflect several different landuses with a single mean value. For instance, it is often the case that pixels on coastlines classified as urbanized areas as a result of mixing highly reflective value of the sand beach and the low value of the water surface. For this reason, discussions on detailed parts of the landuse make little sense when the area is as large as this study area.

The landuse classified as agricultural lands includes sparsely allocated residential areas and open spaces like parks. The maps show considerable number of bare lands. Some of them might be agricultural lands after harvest. Others could be urban uses such as parking lots or unused land.

6. Comparisons

After classifying two scenes with a 13 year gap, the comparisons became possible. A glance at the two classified scenes (Fig. 8 and 9) is enough to understand that agricultural lands surrounding the urban areas had disappeared and became residential areas. However, in order to obtain more detailed information on the trends, the study area was divided into 16 blocks (Fig. 6) for the purpose of obtaining pixel numbers of each landuse in every block.

In addition to the table (Table 1), a color plotter generated map of some landuse changes was drawn. This map follows only the transition of forested areas and agricultural lands in 1972 for the purpose of identifying the trend of urbanization. Fig. 10 shows how forested areas and agricultural lands became used for other purposes.

6-1. Method

A program to extract data on each block was written. This program required information on the boundaries of each block. Then, using this boundary data, the pixel numbers of each landuse in each block was extracted and counted.

In order to obtain the boundary data, A tablet board (Fig. 7), of the main system was used. A 1:200,000 map with enhanced block borders was set on the tablet. The origin of coordinates was set at the left bottom of the study area, which was the first pixel of the last line. The X and Y coordinate values were read by following the boundary lines with the attached cursor at a specific interval. By repeating this process, the data for 16 polygons was stored in the disk.

The program to extract blocks used an algorithm for deciding if a point is inside or outside of a polygon. Table 1 shows the transition of landuses over 13 years in each block.

6-2. Discussion

As expected at the stage of selecting the scenes, the comparisons of the two sets of data caused some trouble. The 1972 data was collected by the LANDSAT 1, which no longer exists. This first LANDSAT satellite had sensors of inferior quality to the current LANDSAT 5. The orbit and the altitude was also different. Though these problems make the comparisons difficult, it was possible to correct the data to some extent.

The more difificult issue was the seasonal differences as explained before. In spite of repeated maximum likelihood method classification with careful selection of the training areas, some inconsistencies between the scenes remained.

Table 1 shows how landuses changed in each block after 13 years. For example, in Kyoto 45.4% of Agricultural land and 48.4% of bare lands of 1972 became urbanized areas. Whereas 96.7% of forested areas remained unchanged. This trend is true of most other areas. This shows that most usable flat areas were already developed as agricultural or residential areas by 1972. In the blocks along Osaka Bay like Kobe area (Block 4 & 5), reclamation was an alternative used to obtain more flat lands.

7. Postscript

With regard to the process, the author felt a shortage of fundamental information. He had an opportunity to use three image processing systems. Each system was equipped with user's manuals, but it was almost impossible to operate these systems just by reading them. Even after repeated readings, unanswered questions remained. This makes a sharp contrast with advanced technical researches. This phenomenon seems to be the most critical obstacle for the prevailing LANDSAT remote sensing. However, this gap seems to be narrowing because some image processing softwares for micro computers have become available on the market. Their prices are moderate, and they can be operated with ease.

The results of the classification were not satisfactory, but they gave us an idea of the landuse trends in the Kansai region which is too large to be grasped by any other means.

For more detailed analysis, using the TM data would be recommended.

Acknowledgments

The author feels grateful to Dr. Takashi Hoshi, and Dr. Tomoyuki Ishida, both of the Science Information Center at the University of Tsukuba, for allowing me to use their TSUKUSYS image processing system. Their assistance was indispensable in accomplishing this research under conditions that the PROSID system of Kyoto University Data Processing Center had memory trouble. He is also indebted to Mr. Takeo Kitazawa and Mr. Yoichi Miyamae of Macro Vision Ltd., for their accurate knowledge on the landuse of the whole Kansai region.

References

1) Japan Remote Sensing Research Group: Processing and Analysis of Images, Kyoritsu Shuppan, Tokyo, 1981
2) WADATE, et al.: Remote Sensing: Asakura Shoten, Tokyo, 1976
3) HOSHI, Takashi: Basics of Remote Sensing, Morikita Shuppan, Tokyo, 1984
4) NASDA Earth Obsevation Center: Handbook of LANDSAT Data Application, Remote Sensing Technology Center, Tokyo, 1982
5) FUJITSU: PROSID User's Manual
6) LILLESAND, Thomas M. & KIEFER, Ralph W.: Remote Sensing and Image Interpretation, Wiley & Sons, New York, 1979
7) HARRINGTON, Steven: Computer Graphics, A Programming Approach, McGraw-Hill Book Company, New York, 1983

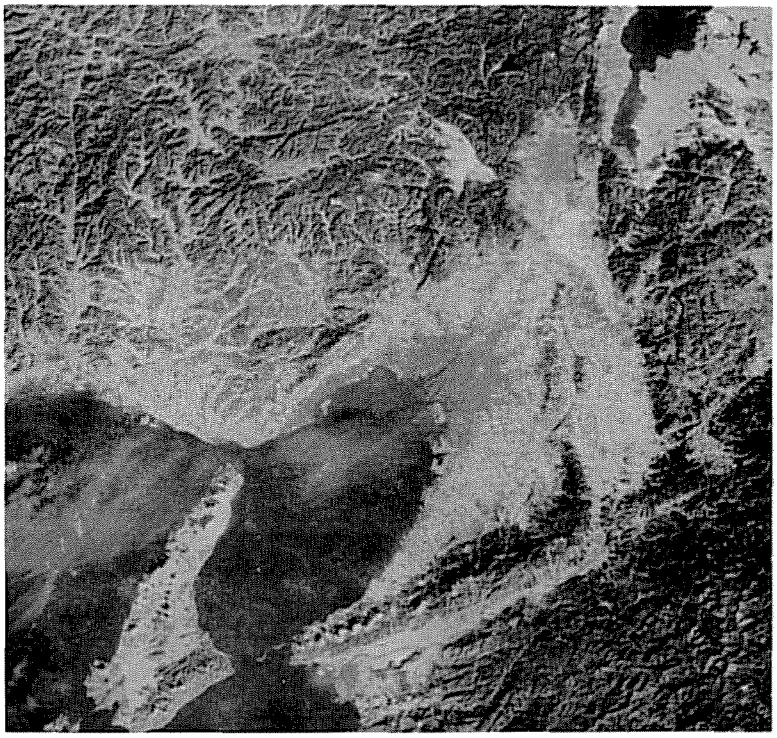

Fig. 1 False color scene of the study area on Oct. 24, 1972.

Fig. 2 False color scene of the study area on June 5, 1985.

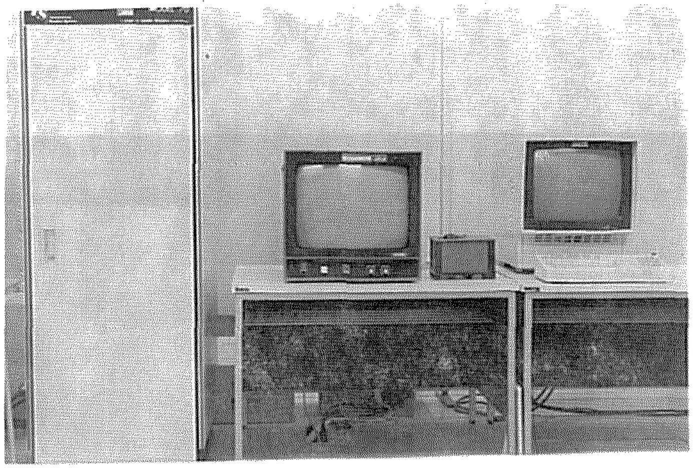

Fig. 3 PROSID image processing unit.

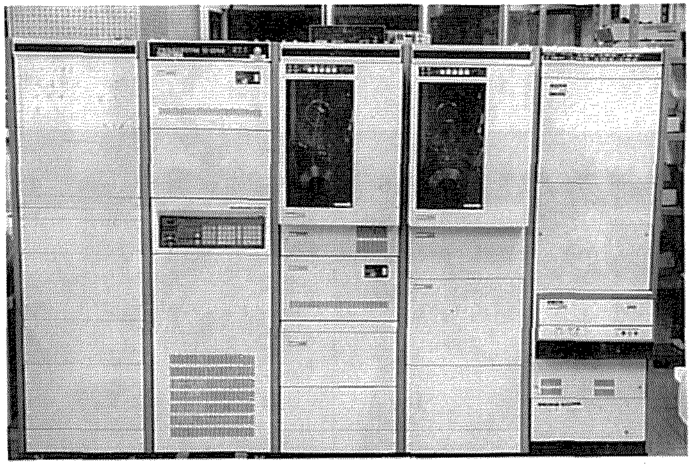

Fig. 4 The central processing unit and the magnetic tape station of the image processing system.

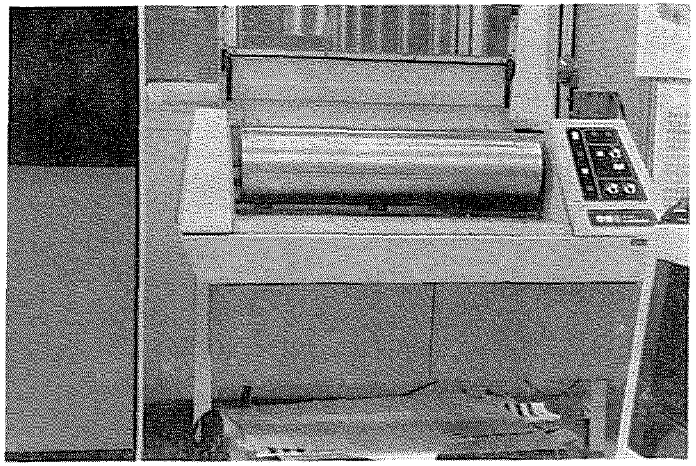

Fig. 5 APPLICON ink-jet color plotter.

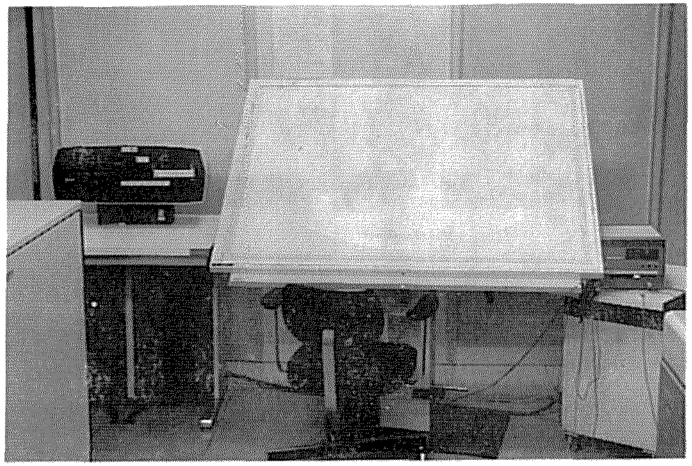

Fig. 7 The tablet used to input boundary data.

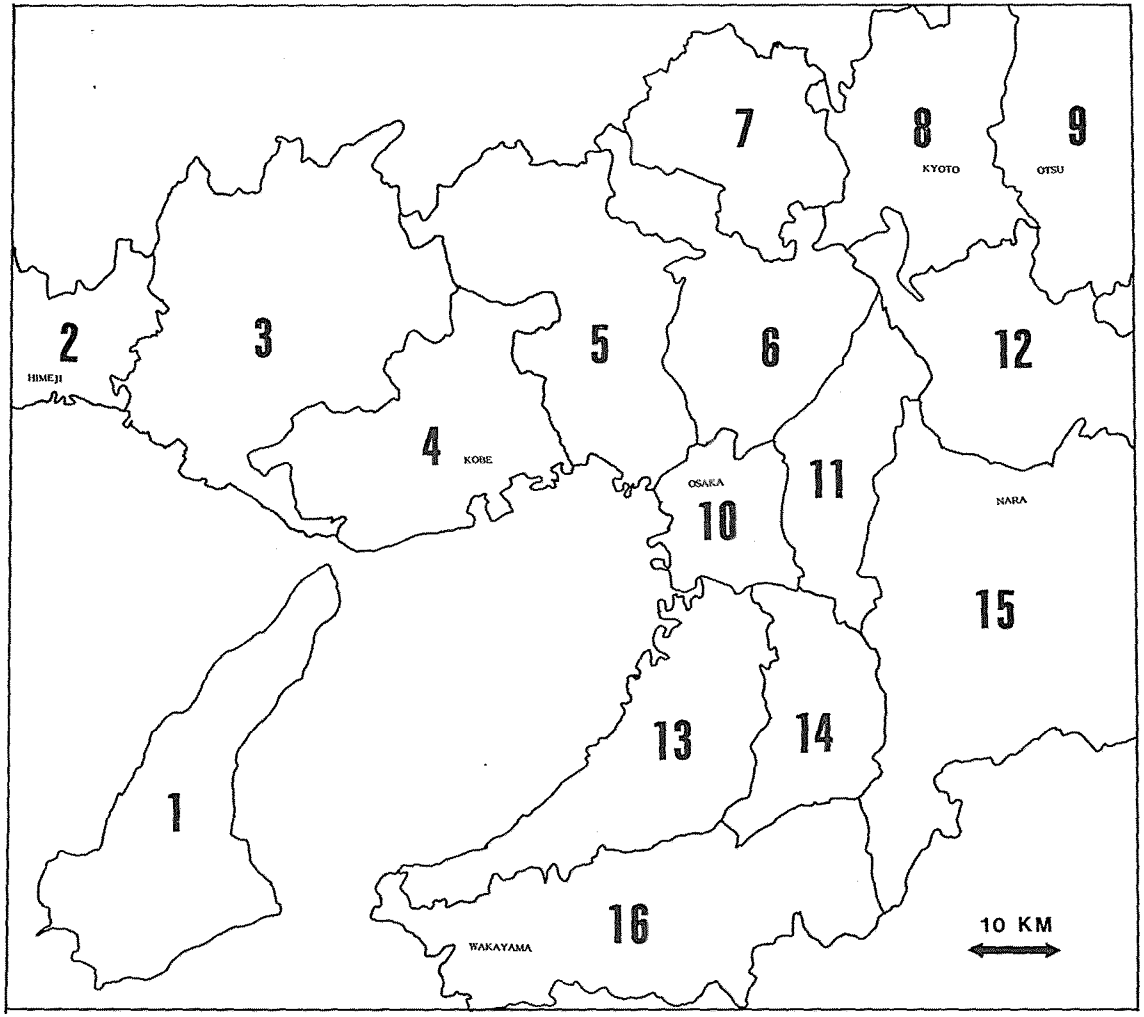

Fig. 6 Map of classified area with block boundaries

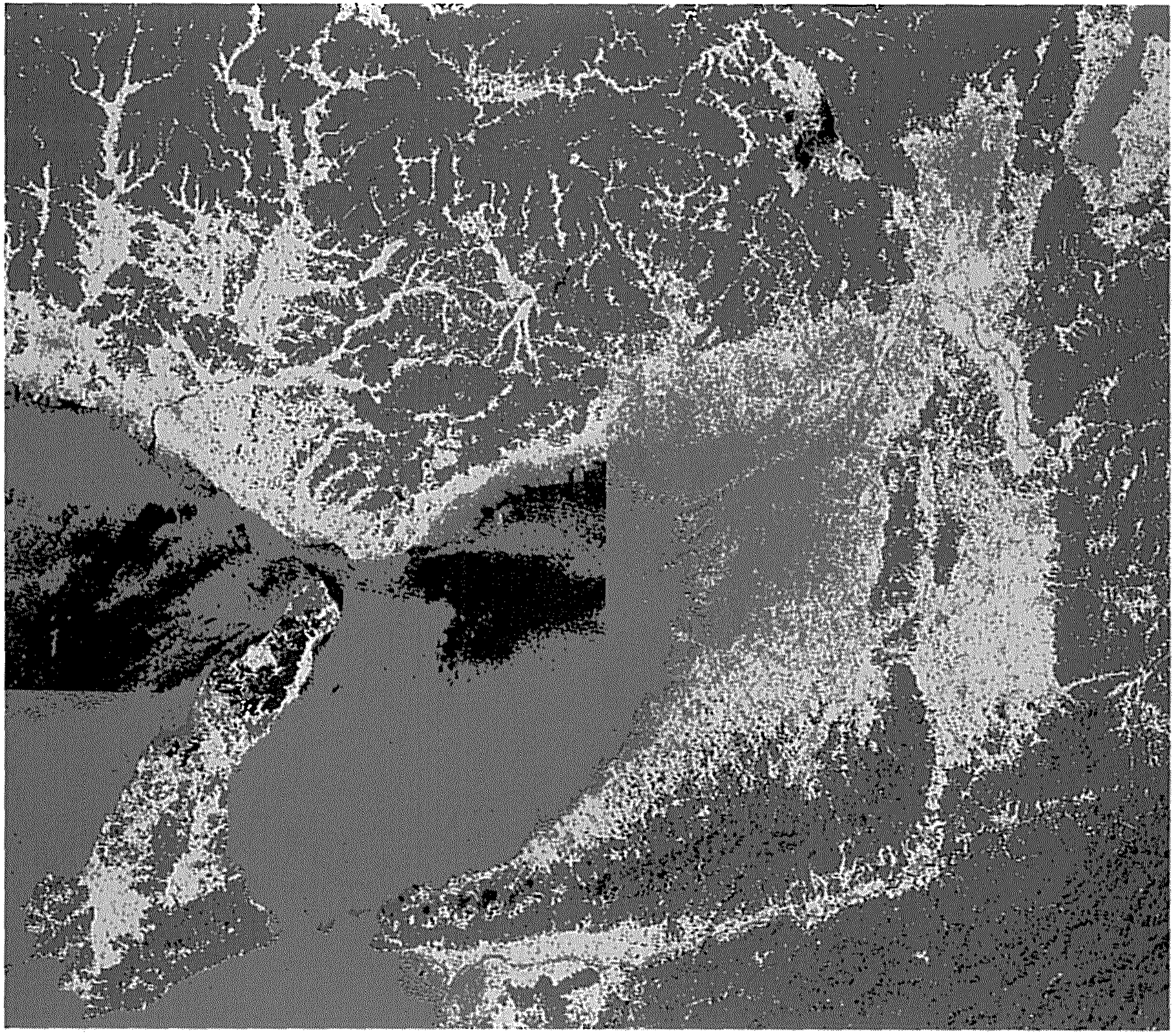

Fig. 8 Landuse in Kansai region in 1972.

Legend:

Blue-Water Surface

Green-Forested Area

Red-Urbanized Area

Yellow-Agricultural Lands

Brown-Bare Lands

Black-Clouds

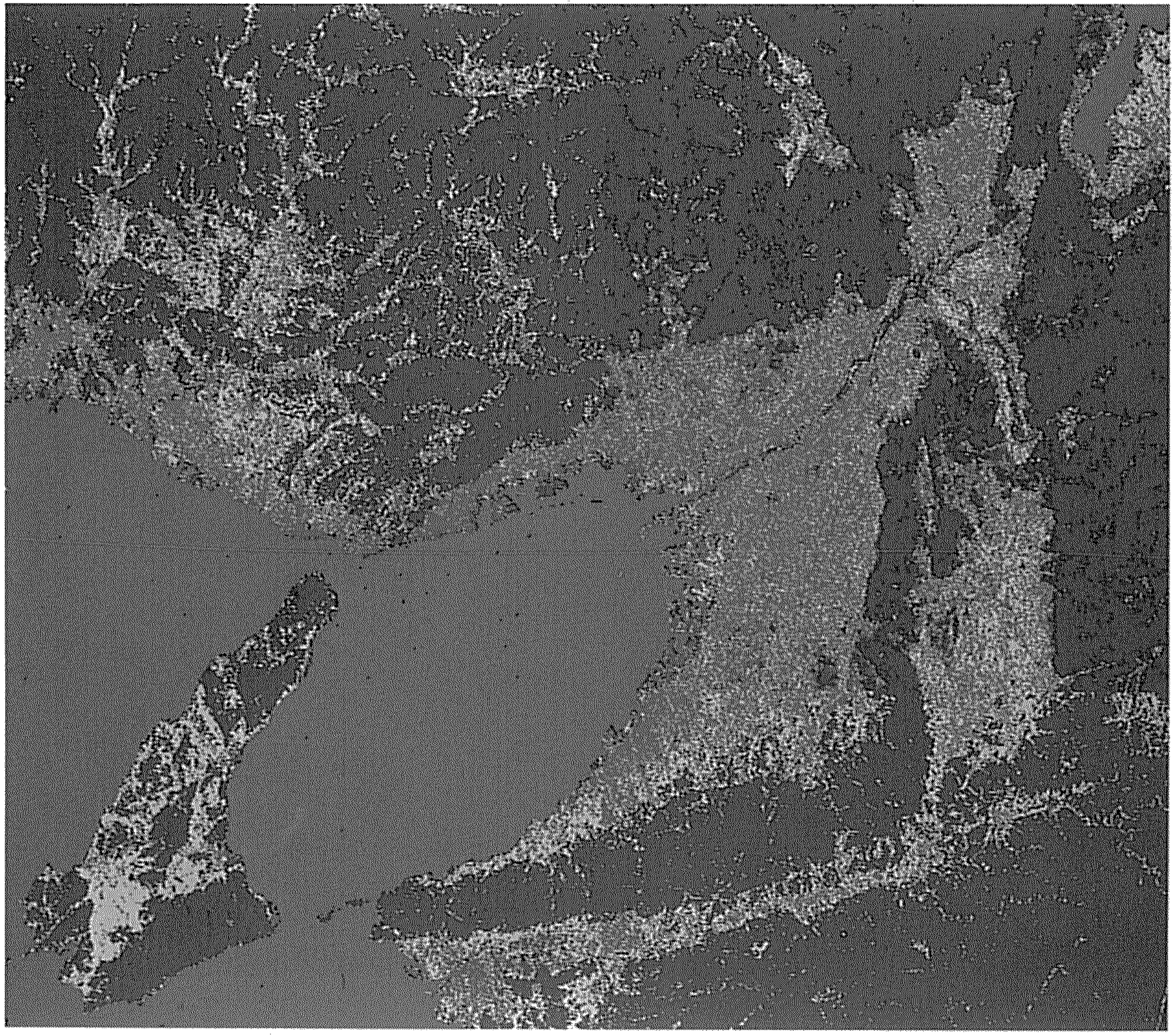

Fig. 9 Landuse in Kansai region in 1985.
Legend : Same as Fig. 8.

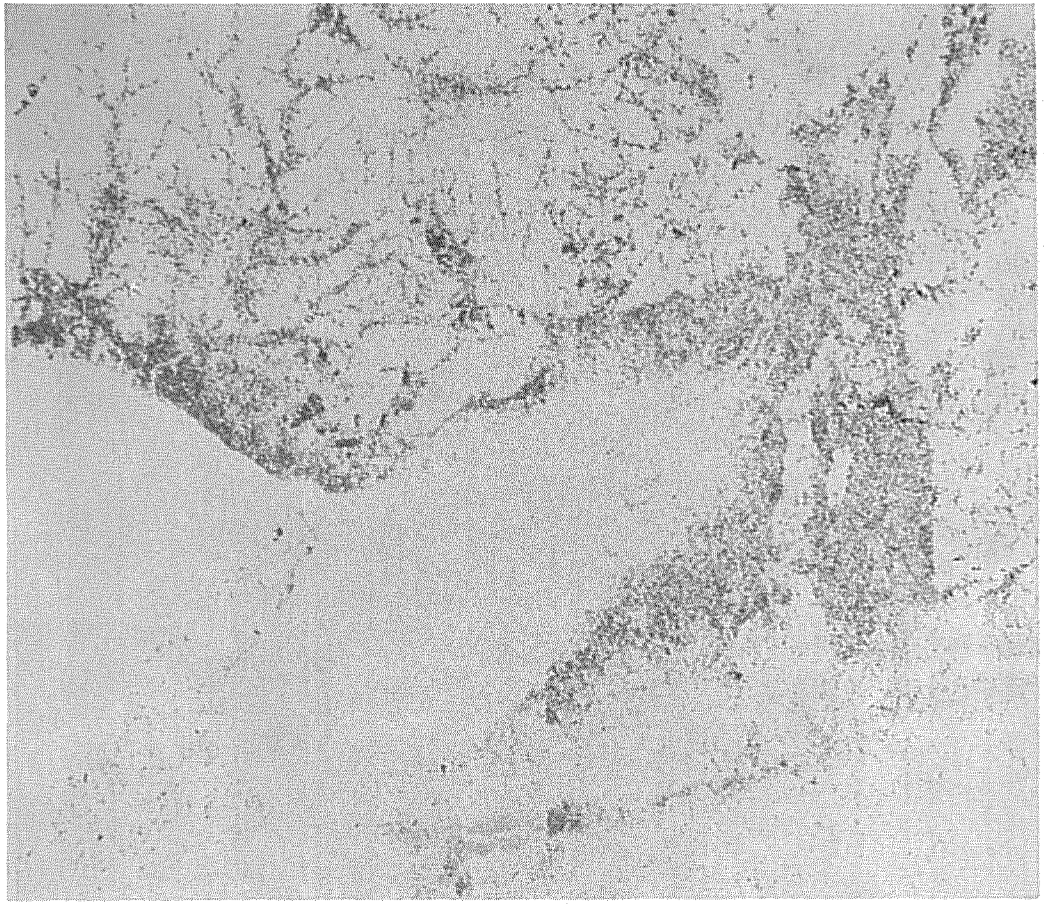

Fig. 10 Changed landuses between 1972 and 1985.
Legend (Original Color):
Black (Green)-Forest to Urbanized Area
Dark Grey(Blue)-Forest to Bare Land
Dark Grey (Red)-Agricultural Land to Urbanized Area
Grey (Yellow)-Agricultural Land to Bare Land

Table 1—1. The landuse change matrix of each block.

*BLOCK 1

'72\'85 :	WATER(%)		FOREST(%)		URBAN(%)		FARM(%)		BARE(%)		TOTAL(%)	
WATER :	202	67.3%	4	1.3%	25	8.3%	11	3.7%	58	19.3%	300	100.0%
FOREST :	8	0.1%	9559	91.7%	283	2.7%	467	4.5%	110	1.1%	10427	100.0%
URBAN :	33	2.3%	708	49.6%	317	22.2%	261	18.3%	107	7.5%	1426	100.0%
FARM :	19	0.2%	3134	40.6%	939	12.2%	3467	44.9%	164	2.1%	7723	100.0%
BARE :	2	0.9%	135	58.7%	20	8.7%	61	26.5%	12	5.2%	230	100.0%
CLOUD :	40	2.3%	1364	78.5%	88	5.1%	231	13.3%	15	0.9%	1738	100.0%
TOTAL :	304		14904		1672		4498		466		21844	

*BLOCK 2

'72\'85 :	WATER(%)		FOREST(%)		URBAN(%)		FARM(%)		BARE(%)		TOTAL(%)	
WATER :	153	71.5%	1	0.5%	34	15.9%	9	4.2%	17	7.9%	214	100.0%
FOREST :	1	0.1%	1494	86.6%	91	3.3%	130	7.5%	9	0.5%	1725	100.0%
URBAN :	23	3.5%	25	3.8%	461	70.6%	112	17.2%	32	4.9%	653	100.0%
FARM :	9	0.3%	560	15.8%	1806	51.1%	1027	29.1%	133	3.8%	3535	100.0%
BARE :	1	1.2%	2	2.3%	44	51.2%	13	15.1%	26	30.2%	86	100.0%
CLOUD :	144	53.7%	12	4.5%	50	18.7%	46	17.2%	16	6.0%	268	100.0%
TOTAL :	331		2094		2486		1337		233		6481	

*BLOCK 3

'72/'85 :	WATER(%)		FOREST(%)		URBAN(%)		FARM(%)		BARE(%)		TOTAL(%)	
WATER :	465	78.2%	6	1.0%	79	13.3%	35	5.9%	10	1.7%	595	100.0%
FOREST :	33	0.2%	11760	81.5%	598	4.1%	1830	12.7%	216	1.5%	14437	100.0%
URBAN :	32	3.2%	58	5.8%	601	60.3%	266	26.7%	40	4.0%	997	100.0%
FARM :	69	0.4%	3114	19.1%	5069	31.1%	7461	45.8%	570	3.5%	16283	100.0%
BAER :	4	0.9%	27	6.1%	226	50.7%	116	26.0%	73	16.4%	446	100.0%
CLOUD :	142	28.8%	78	15.8%	139	28.2%	115	23.3%	19	3.9%	493	100.0%
TOTAL :	745		15043		6712		19		928		23447	

*BLOCK 4

'72\'85 :	WATER(%)		FOCEST(%)		URBAN(%)		FARM(%)		BARE(%)		TOTAL(%)	
WATER :	297	87.9%	0	0.0%	23	6.8%	4	1.2%	14	4.1%	338	100.0%
FOREST :	4	0.0%	8243	80.5%	328	3.2%	987	9.6%	681	6.6%	10243	100.0%
URBAN :	52	3.0%	11	0.6%	1427	81.3%	212	12.1%	54	3.1%	1756	100.0%
FARM :	14	0.2%	2531	35.5%	1694	23.7%	2438	34.2%	457	6.4%	7134	100.0%
BARE :	1	0.2%	35	8.1%	200	46.2%	122	28.2%	75	17.3%	433	100.0%
CLOUD :	378	61.1%	24	3.9%	114	18.4%	58	9.4%	45	7.3%	619	100.0%
TOTAL :	746		10844		3786		3821		1326		20523	

*BLOCK 5

'72\'85 :	WATER(%)		FOREST(%)		URBAN(%)		FARM(%)		BARE(%)		TOTAL(%)	
WATER :	86	63.7%	2	1.5%	15	11.1%	14	10.4%	18	13.3%	135	100.0%
FOREST :	20	0.2%	11387	86.6%	425	3.2%	791	6.0%	531	4.0%	13154	100.0%
URBAN :	73	3.1%	24	1.0%	1583	67.7%	438	18.7%	219	9.4%	2337	100.0%
FARM :	21	0.4%	2026	38.0%	1600	30.0%	1183	22.2%	506	9.5%	5336	100.0%
BARE :	4	0.2%	212	8.7%	1277	52.6%	468	19.3%	469	19.3%	2430	100.0%
CLOUD :	65	48.1%	32	23.7%	16	11.9%	19	14.1%	3	2.2%	135	100.0%
TOTAL :	269		13683		4916		2913		1746		23527	

*BLOCK 6

'72\'85 :	WATER(%)		FOREST(%)		URBAN(%)		FARM(%)		BARE(%)		TOTAL(%)	
WATER :	135	81.3%	0	0.0%	7	4.2%	22	13.3%	2	1.2%	166	100.0%
FOREST :	1	0.0%	4118	82.5%	101	2.0%	560	11.2%	212	4.2%	4992	100.0%
URBAN :	85	2.1%	27	0.7%	2813	70.1%	863	21.5%	223	5.6%	4011	100.0%
FARM :	28	0.5%	550	10.5%	2159	41.1%	1761	33.5%	760	14.5%	5258	100.0%
BARE :	6	0.2%	103	3.4%	1794	59.3%	653	21.6%	467	15.4%	3023	100.0%
CLOUD :	1	0.2%	228	44.6%	48	9.4%	187	36.6%	47	9.2%	511	100.0%
TOTAL :	256		5026		6922		4046		1711		17961	

*BLOCK 7

'72\'85 :	WATER(%)		FOREST(%)		URBAN(%)		FARM(%)		BARE(%)		TOTAL(%)	
WATER :	0		0		0		0		0		0	
FOREST :	1	0.0%	8920	92.8%	364	3.8%	108	1.1%	222	2.3%	9615	100.0%
URBAN :	0	0.0%	6	21.4%	13	46.4%	5	17.9%	4	14.3%	28	100.0%
FARM :	1	0.0%	1162	41.0%	851	30.0%	639	22.5%	181	6.4%	2834	100.0%
BARE :	1	0.1%	257	29.1%	278	31.5%	253	28.7%	93	10.5%	882	100.0%
CLOUD :	0	0.0%	92	20.4%	146	32.4%	180	39.9%	33	7.3%	451	100.0%
TOTAL :	3		10437		1652		1185		533		13810	

Table 1—2.

*BLOCK 8

'72\'85	WATER(%)		FOREST(%)		URBAN(%)		FARM(%)		BARE(%)		TOTAL(%)	
WATER :	2	28.6%	0	0.0%	3	42.9%	1	14.3%	1	14.3%	7	100.0%
FOREST :	2	0.0%	10764	96.7%	189	1.7%	35	0.3%	146	1.3%	11136	100.0%
URBAN :	4	0.2%	9	0.5%	1272	73.0%	404	23.2%	54	3.1%	1743	100.0%
FARM :	10	0.2%	897	20.7%	1967	45.4%	1068	24.6%	391	9.0%	4333	100.0%
BARE :	1	0.1%	321	20.3%	765	48.4%	350	22.2%	142	9.0%	1579	100.0%
CLOUD :	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	1	100.0%
TOTAL :	19		11991		4196		1858		735		18799	

*BLOCK 9

'72\'85	WATER(%)		FOREST(%)		URBAN(%)		FARM(%)		BARE(%)		TOTAL(%)	
WATER :	2748	93.9%	34	1.2%	63	2.2%	63	2.2%	18	0.6%	2926	100.0%
FOREST :	2	0.0%	5116	91.9%	257	4.6%	58	1.0%	135	2.4%	5568	100.0%
URBAN :	27	11.6%	10	4.3%	100	42.9%	83	35.6%	13	5.6%	233	100.0%
FARM :	68	1.2%	1152	20.3%	1995	35.1%	2078	36.6%	384	6.8%	5677	100.0%
BARE :	11	0.8%	235	17.3%	469	32.6%	511	37.7%	130	9.6%	1356	100.0%
CLOUD :	0		0		0		0		0		0	
TOTAL :	2856		6547		2884		2793		680		15760	

*BLOCK 10

'72\'85	WATER(%)		FOREST(%)		URBAN(%)		FARM(%)		BARE(%)		TOTAL(%)	
WATER :	233	63.5%	3	0.8%	54	14.7%	63	17.2%	14	3.8%	367	100.0%
FOREST :	0		0		0		0		0		0	
URBAN :	125	2.2%	28	0.5%	4147	73.5%	1104	19.6%	286	4.2%	5640	100.0%
FARM :	40	9.2%	8	1.8%	200	46.2%	130	31.2%	50	11.5%	433	100.0%
BARE :	4	0.4%	18	1.7%	587	56.5%	252	24.3%	178	17.1%	1039	100.0%
CLOUD :	0		0		0		0		0		0	
TOTAL :	402		57		4988		1554		478		7479	

*BLOCK 11

'72\'85	WATER(%)		FOREST(%)		URBAN(%)		FARM(%)		BARE(%)		TOTAL(%)	
WATER :	1	50.0%	0	0.0%	0	0.0%	1	50.0%	0	0.0%	2	100.0%
FOREST :	0	0.0%	1689	92.5%	53	2.9%	8	0.4%	75	4.1%	1825	100.0%
URBAN :	10	0.5%	7	0.3%	1512	75.5%	346	17.3%	127	6.3%	2002	100.0%
FARM :	4	0.1%	716	16.0%	2125	47.5%	1083	24.2%	542	12.1%	4470	100.0%
BARE :	3	0.1%	257	8.0%	1874	58.0%	659	20.4%	436	13.5%	3229	100.0%
CLOUD :	0	0.0%	0	0.0%	2	50.0%	1	25.0%	1	25.0%	4	100.0%
TOTAL :	18		2669		5566		2098		1181		11532	

*BLOCK 12

'72\'85	WATER(%)		FOREST(%)		URBAN(%)		FARM(%)		BARE(%)		TOTAL(%)	
WATER :	3	33.3%	5	55.5%	0	0.0%	1	11.1%	0	0.0%	9	100.0%
FOREST :	2	0.0%	8864	92.6%	268	2.8%	50	0.5%	392	4.1%	9576	100.0%
URBAN :	0	0.0%	22	13.4%	67	40.9%	59	36.0%	16	9.8%	164	100.0%
FARM :	4	0.1%	1159	23.4%	1728	34.9%	1415	28.6%	639	12.9%	4945	100.0%
BARE :	0	0.0%	283	22.2%	425	33.4%	239	18.8%	327	25.7%	1274	100.0%
CLOUD :	0	0.0%	1	50.0%	1	50.0%	0	0.0%	0	0.0%	2	100.0%
TOTAL :	9		10334		2489		1764		1374		15970	

*BLOCK 13

'72\'85	WATER(%)		FOREST(%)		URBAN(%)		FARM(%)		BARE(%)		TOTAL(%)	
WATER :	262	64.7%	5	1.2%	54	13.3%	61	15.1%	23	5.7%	405	100.0%
FOREST :	1	0.0%	6341	82.7%	258	3.4%	836	10.9%	233	3.0%	7669	100.0%
URBAN :	96	3.1%	203	6.5%	1995	64.0%	660	21.2%	163	5.2%	3117	100.0%
FARM :	30	0.4%	859	11.8%	3003	41.4%	2633	36.3%	732	10.1%	7257	100.0%
BARE :	7	0.5%	17	1.1%	881	58.3%	331	21.9%	274	18.1%	1510	100.0%
CLOUD :	3	0.2%	804	60.1%	131	9.8%	317	23.7%	82	6.1%	1337	100.0%
TOTAL :	399		8229		6322		4838		1507		21295	

*BLOCK 14

'72\'85	WATER(%)		FOREST(%)		URBAN(%)		FARM(%)		BARE(%)		TOTAL(%)	
WATER :	0	0.0%	0	0.0%	1	100.0%	0	0.0%	0	0.0%	1	100.0%
FOREST :	1	0.0%	4963	86.5%	54	0.9%	494	8.6%	226	3.9%	5738	100.0%
URBAN :	7	1.6%	9	2.1%	248	56.6%	147	33.6%	27	6.2%	438	100.0%
FARM :	6	0.2%	471	13.1%	1375	38.1%	1189	33.0%	567	15.7%	3608	100.0%
BARE :	2	0.2%	64	7.1%	509	56.2%	209	23.1%	122	13.5%	906	100.0%
CLOUD :	0	0.0%	328	59.6%	20	3.6%	167	30.4%	35	6.4%	550	100.0%
TOTAL :	16		5835		2207		2206		977		11241	

Table 1—3.

*BLOCK 15

'72\'85 :	WATER(%)		FOREST(%)		URBAN(%)		FARM(%)		BARE(%)		TOTAL(%)	
WATER :	1	100.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	1	100.0%
FOREST :	8	0.0%	17660	85.5%	697	3.4%	1408	6.8%	885	4.3%	20658	100.0%
URBAN :	4	0.8%	19	3.8%	268	53.0%	198	39.1%	17	3.4%	506	100.0%
FARM :	18	0.1%	2171	13.9%	5502	35.3%	6441	41.4%	1440	9.2%	15572	100.0%
BARE :	4	0.2%	278	13.9%	901	45.0%	510	25.4%	311	15.5%	2004	100.0%
CLOUD :	0	0.0%	191	43.2%	33	7.5%	185	41.9%	33	7.5%	442	100.0%
TOTAL :	35		20319		7401		8742		2686		39183	

*BLOCK 16

'72\'85 :	WATER(%)		FOREST(%)		URBAN(%)		FARM(%)		BARE(%)		TOTAL(%)	
WATER :	139	55.6%	8	3.2%	28	11.2%	5	2.0%	70	28.0%	250	100.0%
FOREST :	5	0.0%	11396	90.3%	186	1.5%	833	6.6%	202	1.6%	12622	100.0%
URBAN :	101	5.7%	152	8.6%	983	55.9%	248	14.1%	276	15.7%	1760	100.0%
FARM :	19	0.4%	876	17.0%	1716	33.2%	2124	41.1%	433	8.4%	5168	100.0%
BARE :	0		0		0		0		0		0	
CLOUD :	5	0.9%	408	73.0%	13	2.3%	109	19.5%	24	4.3%	559	100.0%
TOTAL :	269		12840		2926		3319		1005		20359	

* The unit is the number of pixels. The percentage is based on the individual landuse of 1972.